ON THE

SHAPE OF TRANSVERSE WOUNDS

OF THE

BLOODVESSELS

IN RELATION TO THEIR PHYSIOLOGY.

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Everyone knows that the shape which wounds of arteries assume mainly depends upon their direction; that while a longitudinal wound remains a mere slit, a transverse wound gapes widely, its edges separating in proportion to its extent; and that wounds in other directions gape more or less according to their obliquity. But although these facts are familiar ones, they have yet attracted very little attention. In many works on surgery they are not even mentioned; in none are they explained. Amongst modern authors, Guthrie and Liston are conspicuous for the description they give of them. Liston, and Miller after him, have in their works introduced sketches of the various shapes of different wounds of arteries.

In these and in other works in which the fact is noticed, the longitudinal wound is described as remaining a mere fissure, the oblique wound as becoming fusiform, and the transverse wound as becoming circular or oval according to its extent.

"The longitudinal appears to produce the slightest possible, or perhaps scarcely any, separation; the oblique occasions a separation proportioned to its extent; and the transverse, however small, seems to produce a circular aperture in the parietes of the artery.

"This circular appearance of transverse wounds will, of course, be lost if the wound is very considerable. It appears to have been a very old observation, that wounds of arteries are circular; it has been noticed by Wiseman, Petit, Monro, and Haller; but I believe that the appearance is confined to punctures or small transverse wounds of the artery, and depends chiefly on the retraction of the divided fibres."*

"When an artery is cut transversely, in man, to one-third or one-fourth of its circumference, it forms the same circular opening as in animals."†

"The degree of gaping in transverse wounds depends upon the extent to which the parietes are cut; an incision, for instance, involving a third of the canal, will be seen to give rise to a round opening; one involving two-thirds causes a large oval opening."‡

The description given of transverse wounds is not quite accurate. I do not think the angles of the wound, under any circumstances, entirely disappear. In none of my experiments have I failed to discover them upon a careful examination. Where the wound is very extensive, they become widened and obscured, but even then they are still visible. They are, of course, much more plainly marked in the larger vessels; and in the smaller ones they can scarcely be discerned with the naked eye, although with the aid of a lens they will be at

* Jones on Hæmorrhage, pp. 114, 115, and 186.

† Guthrie on Diseases and Injuries of Arteries, p. 213. 1830.

‡ Liston's Practical Surgery, p. 151. 1837.

once detected. At the same time, the edges of the wound towards the centre become raised, and perhaps slightly everted. In fact, it is more accurate to describe these transverse wounds as becoming wedge-shaped rather than circular (Figs. 1 and 2). This is important in relation to the structure and properties of the arterial coats.

Fig. 1.

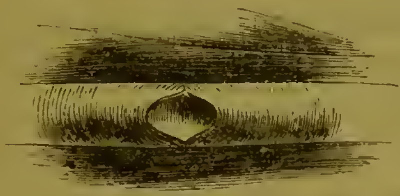

Fig. 2.

What is the cause of the various shapes thus assumed by different wounds?

If an artery be simply exposed, without any disturbance, in a living animal, and a transverse wound be made in it, the edges will immediately separate. The wound will gape and assume the shape just now described. If at the expiration of some hours the animal be killed, and the wound carefully examined, it will be seen to have undergone no change of shape. Even if the animal be allowed to bleed to death, that the muscular fibres of the artery may have the greatest "stimulus" to contract,* although the artery will be more than usually diminished in its calibre, the characters of the wound will remain unaltered. If the wound be examined some days after death, no change in its shape will be detected.

* Hunter's Works, vol. iii. p. 166.

If the portion of artery containing the wound be dissected out and removed, the wound will at once close; its edges will come into contact; it will appear as a simple fissure, like a longitudinal wound.

If the same operation be repeated upon an artery of an animal or of the human subject which has been dead for three or four days* or more, the wound will still assume the same shape; no difference in this respect can be detected. If dissected out, as in the last case, the wound will close at the instant of division.

If a portion of artery, some two or three inches long, be dissected out and removed from an animal or the human subject, and a transverse wound be made in it, the edges will remain in contact. It will appear as a mere slit. If now the artery be stretched, the wound will gape, and assume the shape of a wound made in the living or dead artery *in sitû*. As the artery is allowed to recoil again, the wound closes.

Before I draw any conclusions from these experiments, I would notice an objection which has been raised by Guthrie and some other surgeons to experiments on the arteries of animals as applicable to the physiology of the arteries of man. The difference between them has been very much exaggerated.† But admitting the fact that they differ somewhat in their structure and properties, it is a difference of degree merely, not of kind. All examinations and experiments tend to prove this. Therefore, although in certain delicate questions, such as those relating to secondary hæmorrhage, it is not perhaps safe to draw direct conclusions from experiments on animals as to what occurs in the human subject; yet, in

* See Hunter on the Duration of Muscular Power in the Arteries after Death. Works, vol. iii. pp. 157-8-9.

† See Guthrie, op. cit., p. 209.

relation to the broader and more general facts, I do not think that the applicability of such experiments can be denied.

I conclude, then, from these experiments, that wounds assume the same shape in the dead as in the living artery, and that it must therefore be due to their physical property; that is, to their elasticity, and not in any way to the muscular tissue they contain, the function of which ceases with its life.

That the shape assumed by transverse wounds must also be due to the condition in which the arteries are naturally placed, since it does not occur when the artery is dissected out and removed.

The fact that transverse wounds of the arteries thus gape implies, therefore, not only elasticity, but a natural state of tension also.

If a transverse wound be made in a portion of vulcanized rubber tube, and the tube be then gradually stretched, the shape of the wound will be seen to alter. At first, as its edges separate, the angles remain, and it appears wedge-shaped, as in the case of the arteries. As the stretching is continued, the angles gradually disappear until no trace of them remains, and the wound becomes really circular or oval. As the degree of tension is increased, the wound becomes more and more extended.

The difference between the arteries previously described and the elastic tube depends upon this: there is no limit to the elasticity of the tube; it yields in proportion to the amount of force employed to stretch it until it tears. This is not the case with the artery. Its physical properties differ in this respect: there is a distinct and abrupt limit to its elasticity. If a portion of an artery be similarly treated, it will not continue to yield indefinitely, but after elongating to a certain extent only, a sudden resistance will be experienced,

beyond which no increase of force can stretch the artery without lacerating its texture. This property is doubtless mainly due to that inelastic element, the white fibrous tissue which exists in the arterial tunics, and must be so arranged as to check at a certain point any further yielding of the elastic tissue. For until it tears there is no limit to the extensibility of pure elastic tissue. If a strip of elastic tissue be taken from the ligamentum nuchæ, and a similar strip from the aorta, and both be stretched, the contrast is very obvious. The arteries are similar in this property to elastic webbing, in which the elasticity of the caoutchouc is limited by the inelastic fabric which invests it. Thus may be explained the fact that transverse wounds of arteries do not, as in purely elastic tubes, become regularly circular, but always retain their angles. It is due to the tissue which abruptly limits their extensibility.

In his admirable chapter on the Structure of Arteries, in which their properties are described with such characteristic accuracy, Hunter strangely passes over this most important fact: that naturally the arteries are in a state of tension; that they are always more or less stretched, and ever ready to recoil by virtue of their elasticity whenever the opposing force is removed. When speaking of the "three states" of an artery, he is evidently referring to its diameter rather than to its length, for he speaks of the natural or middle state as a state of rest, opposed to either a stretched or contracted condition. "There are three states in which an artery is found, viz.:—1st, the natural pervious state; 2nd, the stretched; and 3rd, the contracted state, which may or may not be pervious. The natural pervious state is that to which the elastic power naturally brings a vessel which has been stretched beyond, or contracted within, the extent which it held in a

state of rest. The stretched is that state produced by the impulse of the blood in consequence of the contraction of the heart, from which it is again brought back to the natural state by the elastic power, perhaps assisted by the muscular. The contracted state of an artery arises from the action of the muscular power, and is again restored to the natural state by the elastic." In another place he says: "As elastic bodies have a middle state, or state of rest, to which they return after having been dilated or contracted by any other power, and as they must always be acted upon before they can react, the use of elasticity in the arterial system will be very evident. It is by this means that the vessels adapt themselves to the different motions of the body, as flexion and extension. So that one side of an artery contracts while the other is elongated, and the canal is always open for the reception of blood in the waved, stretched, or relaxed state."* It is clear that the first portion of these remarks will hold good for the calibre of arteries only, for in regard to their length the natural state is one of tension, seeing that, by virtue of their elasticity, they are capable of contraction beyond the state in which they naturally exist. Hunter does not speak of this; he nowhere mentions that the elastic force is *constantly* in action in the arteries even against the natural state.

So again Bichat, in the following passage, passes by the fact very closely, and yet curiously misses it:—"In the ordinary state, most of our organs are held in a certain degree of tension by various causes; the voluntary muscles by their antagonists; the hollow muscles by the different substances they enclose; the vessels by the fluids which circulate in them; the skin of one portion by that of neighbouring parts; the alveolar walls by the teeth which they contain, &c. Now,

* Op. cit., vol. iii. pp. 159 and 171.

if these causes cease, contraction supervenes. Divide a long muscle, its antagonist shortens; empty a hollow muscle, it contracts; prevent an artery from receiving blood, it becomes a ligament; cut through the skin, the edges of the incision separate, drawn by the retraction of the neighbouring portions; extract a tooth, the alveolus becomes obliterated, &c. In these cases it is the cessation of the natural extension which determines the contraction."*

Nor has this natural condition of arteries attracted the attention of subsequent authors. The fact, when mentioned, is instantly recognised, and strikingly shown by the retraction of the ends of a divided artery, but it has rarely received even a passing notice. For that this retraction of the ends of a divided artery is wholly due to elasticity, and in no way influenced by muscular contraction, is proved by the fact that a dead artery retracts on division as much as a living one. This simple experiment is very easily performed.

Evidence that this natural condition of the arteries is connected with the ever-varying alterations of extent and direction to which they are subjected in the movements of the body, and that by it their patency and efficiency are secured under every contingency, is furnished by the fact that those arteries are naturally most tense which are most affected by the movements of the part. For the same reason a limit is set to their extensibility; for the calibre of the canal is diminished in proportion to its elongation. The natural degree of tension may be roughly estimated by the extent to which the edges of transverse wounds separate, but much more accurately by the extent to which the ends of a divided artery retract.

For example: the following arteries were simply exposed and divided; the ends separated to this extent:—

* Recherches Physiologiques sur la Vie et la Mort, p. 100. 1805.

Common carotid	$0\frac{7}{10}$ inch.
Brachial — in middle of arm	$0\frac{8}{10}$,,
,, opposite internal condyle .	1 ,,
Common iliac	$0\frac{6}{10}$,,
,, ...	$0\frac{5}{10}$,,
,, ...	$0\frac{6}{10}$,,
External iliac	$0\frac{7}{10}$,,
Femoral — immediately above canal .	$0\frac{9}{10}$,,
Popliteal	$1\frac{3}{10}$,,

Thus the extent to which the divided extremities of arteries retract is a measure of their tension, not of their elasticity.

But the retraction, although generally so considerable, is yet never a measure of the full extent of recoil of which an artery is in itself capable. For instance, if an artery be merely exposed and divided *in sitû*, and, after the extent of separation of the ends is determined, the portion of artery beyond either extremity be dissected out from the surrounding parts with which it is connected, the ends will be much farther apart than before; thus showing that, under any circumstances, its complete recoil is prevented by its attachment to the tissues around.

The relation which the natural condition of an artery bears to the extreme limits of its relaxation or tension is more perfectly shown by the following experiment:—

A portion of an artery is exposed and accurately measured. It is then dissected out and removed, and again measured. It is then stretched to its extreme limit, and measured a third time. The first gives its length *in sitû;* the second, when completely contracted; and the third, when fully extended. For example: The head being on a level with the body, a portion of the right common carotid artery of a man measured when exposed *in sitû* $1\frac{4}{10}$ inch. It was then carefully isolated and accurately divided: when removed, it

measured $1\frac{1}{10}$ inch. It was now fully stretched, and measured $1\frac{6}{10}$ inch.

The following table gives the result of some of these experiments:—

	Relaxed. Inches.	Natural. Inches.	Stretched. Inches.
Common carotid	1	$1\frac{2}{10}$	$1\frac{3}{10}$
Femoral, in middle of thigh	$0\frac{6}{10}$	1	$1\frac{1}{10}$
Abdominal aorta	$1\frac{7}{10}$	2	$2\frac{1}{10}$
Internal mammary	$1\frac{1}{10}$	$1\frac{4}{10}$	$1\frac{6}{10}$
,, ,, ...	$1\frac{2}{10}$	$1\frac{4}{10}$	$1\frac{6}{10}$
Common carotid (of an old woman in whom the vessels contracted less than usual)	$1\frac{2}{10}$	$1\frac{3}{10}$	$1\frac{6}{10}$
Carotid (of a live dog) . .	$0\frac{6}{10}$	1	$1\frac{1}{10}$

It is worthy of remark, that it is only in certain parts of the body, where the influence of movement is most extensive, that we can by any amount of relaxation bring the retracted ends into apposition. Thus: if the brachial or femoral artery be divided in the middle of the arm or thigh, by no possible contrivance of position can the retracted ends be brought together again; indeed, the degree of separation can scarcely be diminished. But if the brachial artery be divided in front of the elbow, or the popliteal artery behind the knee, then forcible flexion will bring the ends into contact.* The same

* It is well known that when the elbow is acutely flexed, the pulse at the wrist becomes imperceptible; and a similar effect upon the circulation below is produced by extreme flexion of the knee. This fact is important, and illustrative of the purpose which the tension of the vessels fulfils. In the course of some ingenious observations on the arteries of the limbs, Mr. Nunn notices the free anastomosis of vessels about the elbow and knee joints, and, alluding to the subject of extreme flexion, asks, "Has not this arrangement some relation to the nature of the movement proper to the joint—to the extreme flexion of which it is capable, and which it so frequently undergoes?"—*Observations and Notes on the Arteries of the Limbs.* By T. W. Nunn. 1858.

Popliteal aneurism has been successfully treated by extreme flexion of the

remark applies to the approximation of the edges of transverse wounds; and this is a fact of some more immediate practical application. For instance: by no management of position or relaxation of the part can the edges of transverse wounds, as a general rule, be approximated; it can only be accomplished in such situations as those just now indicated.

By similar experiments, the veins may be shown to be naturally in the same condition—that is, in a state of tension; and, judging from the extent to which they recoil when divided, this is at least equal to that of the arteries. For example:—

Internal jugular	1 inch.
Popliteal (of same subject as artery) .	$1\frac{3}{10}$ „
Saphena, in middle of thigh	$1\frac{6}{10}$ „

In the dead subject, and in living animals under chloroform, I have often divided artery and vein on the same level by a simple cut, and also after dissecting them out separately and isolating them to the same extent. The very general rule has been, that they retracted in an equal degree. Therefore, wounds of veins assume similar shapes, modified to a certain extent by the texture of the venous coats. Thus the edges of longitudinal wounds yield and gape somewhat; and transverse wounds sometimes yield to such a degree—partly from

knee. Two cases of this kind have been recently related to the Medical and Chirurgical Society. The principle of this plan of treatment may be, I think, satisfactorily explained by reference to the facts just stated. The canal of the artery, and consequently the current of blood through it, is thus interrupted immediately beyond the aneurism; while the free and abundant arterial and venous anastomosis around the joint is admirably adapted to avert all mischief from the prolonged interruption of the circulation through the main artery and vein. These cases are especially interesting in relation to the subject of this paper; for if the explanation here offered be a valid one, they illustrate in a remarkable manner the points previously referred to.

the tension, and partly from the greater delicacy of the venous coats—as to assume the appearance of longitudinal fissures. (Fig. 3.) As soon as the vein is divided and allowed to retract, the wound becomes a transverse slit.

FIG. 3.

I need not further allude to these experiments, which were simply repetitions of those on the arteries. The following table, which exhibits the measurements of a few veins *in sitû*, and when contracted and extended, may be compared with the previous one:—

	Relaxed. Inches.	Natural. Inches.	Stretched. Inches.
Internal jugular	$1\frac{2}{10}$	$1\frac{4}{10}$	2
Femoral, in middle of thigh (of same subject as artery .	$0\frac{6}{10}$	1	$1\frac{1}{10}$
Internal mammary . . .	1	$1\frac{3}{10}$	$1\frac{4}{10}$
" " . . .	$1\frac{1}{10}$	$1\frac{4}{10}$	$1\frac{5}{10}$
Internal jugular (of same old woman as artery) . .	1	$1\frac{3}{10}$	$1\frac{6}{10}$
External jugular (of live dog)	$0\frac{6}{10}$	1	$1\frac{1}{10}$

A state of tension is of course by no means peculiar to the bloodvessels. All the tissues whose pliancy will admit of it are naturally more or less tense;* some constantly, some

* Bichat criticises Haller, Blumenbach, Barthez, and others, for confounding elasticity with contractility. It appears to me that there is less confusion in Haller's description of his "Vis Mortua," than in the passage previously quoted from Bichat.

occasionally. In some it is not due to the physical property of elasticity. But the tension characteristic of the vessels is constant, and due to elasticity alone. Moreover, it far exceeds that of all other tissues, because they are tubes whose patency under every condition of movement and position must be maintained.

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